Office for Information Resources
GIS Services

Spatial Data Architecture for the State of Tennessee

Version	Date	Description
v0.99	01/04/2002	Internal Draft
V1	01/18/2002	Public Release
V2	05/16/2006	Update

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Executive Summary

Geographic Information Systems (GIS), used to manage, analyze and display information of a spatial nature, have been in use within State agencies for more than 30 years. Initial use was limited to small groups within individual agencies working on very specific projects of limited scope. The nature of this type of implementation was such that software and hardware costs were proportionately high; while the costs to produce required data sets and the associated labor were relatively low. And with limited implementation, source data was relatively scarce and often it was more cost effective to produce necessary data than research and acquire it from external sources.

Since those early years, agency implementation of GIS has become widespread. So much so that all of the larger State agencies are currently using the technology, and most of the smaller agencies and commissions are actively engaged in application of the technology on a variety of levels. Software and hardware costs have dropped dramatically, while the functionality of the software and the computing capability of the hardware platforms have both dramatically expanded and increased. This has lead to an ever-increasing need by more and more agencies for data that is of higher accuracy, and greater detail for use in the analysis of an individual issue, problem, or site. And greater accuracy within the context of spatial data equates to greater costs to produce, manage, and maintain these data sets.

The purpose of the Spatial Data Architecture is to establish roles and responsibilities, establish and implement strategic and tactical planning processes, identify critical issues, and provide a sound framework so that any investment of State funds in this technology is maximized.

First, the vision of the Spatial Data Architecture is presented. This establishes the need for the Architecture, and provides a foundation for the guiding principals of the Architecture. Each of the six principals is then examined in detail. The physical architecture elements of hardware and software components are then present and discussed. Finally, a framework for roles and responsibilities of GIS Services, and agencies is then offered.

The Spatial Data Architecture, being dependent upon many factors that are themselves dynamic and constantly changing, is intended to provide a stable foundation for GIS implementation and use within Agencies. Important among the many factors included in the Architecture is that it is expected that many issues as yet unknown will be a result of the establishment and implementation of the Architecture. As such, the processes that are started with the release of this document will prove to be challenging, lively, and dynamic as we move forward. It is understood then that this document, while representing a foundation, will be dynamic and updated periodically to reflect changing conditions.

Vision

Geographic Information Systems (GIS) manage, analyze, and display spatial data. Spatial data is made up of two components, a spatial component and an attribute component. The spatial component is a geometric representation of a real world object or feature, while the attribute component describes something about the feature. Spatial data can be referenced explicitly using a street address or geographic coordinate, or it can be referenced implicitly using a code to reference a defined geographic area such as a census tract, zip code, or county boundary. Upwards of seventy-five percent of government data can be considered spatial data by this definition. State government invests substantial resources in the development and use of spatial data. Effective planning can lead to increased efficiencies and benefits across the enterprise of State government.

The Spatial Data Architecture (SDA) addresses the support for geospatial data and applications within the State of Tennessee's Information Systems Plan and Technical Architecture. This enterprise architecture will present the foundation for the technical implementation of the Tennessee Base Mapping Program (BMP) and provide the framework for developing coordinated and comprehensive geospatial systems planning at the agency level.

The *Tennessee Base Mapping Program* is a five-year program to provide statewide coverage of basic spatial data in partnership with local governments.

The GIS Services section in the Office for Information Resources (OIR) is the unit responsible for spatial data and geospatial technologies. Developing and implementing the SDA fulfills a strategic objective to develop and implement an enterprise-level GIS architecture. The SDA will also serve to define and implement subsequent objectives related to enterprise geospatial data and application development for State government.

Principles of the Spatial Data Architecture

1) Spatial data, like other information resources maintained by the State, is a valuable resource and must be easily shared among agencies.
2) The State and State agencies will develop and implement comprehensive GIS strategies through continuous geospatial systems planning.
3) Hardware and software infrastructure for data storage and application development will be economical, scalable, and responsive.
4) A GIS personnel classification system is critical to the success of GIS in State government.
5) A comprehensive GIS strategy will generate additional opportunities for interfacing programs between and among local, state, and federal government.
6) Distribution and access policy for spatial data will be coordinated and consistent across the enterprise of State government.

Principle #1: Spatial Data Sharing

The collection and maintenance of spatial data is an expensive undertaking. Prior to an enterprise vision, agencies developed geospatial data to meet their immediate needs. This has led to the development of redundant and sometimes incompatible data products and applications. Spatial data sharing is further hindered by the inefficient nature of unidirectional and oftentimes informal data sharing relationships and transfers between agencies. The process of data sharing is not impossible in this environment, but it is hardly optimized to its fullest potential.

Conflation is the process of extracting data from one spatial data set and incorporating it into another spatial data set for the purpose of improving quality or accuracy.

The products of the Base Mapping Program are intended to provide the minimum elements for analytical and cartographic products and services required by agencies. As agencies integrate and adapt BMP data for their operations, *de facto* interagency sharing will be enabled since agencies will build applications based on a common source for geospatial data. Through a process of conflation, agencies will be able to integrate legacy attribute components to the high-accuracy spatial components of BMP data. Access to attribute components between agencies can be managed through traditional relational database methods. Applications using BMP data through the SDA will have access to the most current information as it is updated throughout State government.

The goal of this enterprise spatial data architecture is to promote the coordinated development and utilization of geospatial data in State government. Maintaining a single common source for geospatial data is the most direct method for maximizing the State's investment in the BMP. Duplicating portions of the BMP database promotes divergent update paths that will be expensive and potentially impossible to reconcile. Multiple versions of BMP data must be minimized and authorized only when accompanied with a plan for transactional updates to the BMP database.

Maintenance is the continual process of keeping spatial data up-to-date.

The role of maintenance is important in the context of data sharing. Agencies will become custodians to data layers involved within their discipline responsibility. For example, the Department of Property Assessments in the Office of the Comptroller will be the custodian of parcel data. GIS Services will be the custodian of orthoimagery. Custodianship of the remaining BMP layers will evolve to the most responsible agency or agencies. Once the infrastructure necessary to support the requirements of BMP maintenance is implemented, agencies will have the option to take advantage of this infrastructure for centralized access and distribution of geospatial data themes beyond those of the BMP.

An important component necessary to enable geospatial data sharing is metadata. The Federal Geographic Data Committee (FGDC) maintains the Content Standard for Digital Geospatial Metadata (CSDGM). The CSDGM prescribes minimal and recommended geospatial dataset attributes necessary to document and evaluate spatial data. Metadata can be compiled using tools integrated within GIS applications, or managed by dedicated metadata applications.

Principle #2: Continuous Geospatial Systems Planning

The Spatial Data Architecture is intended to serve as a foundation for continuous geospatial systems planning. Agency planning is a strong component of the SDA vision. The level of interagency communication necessary to support an effective enterprise architecture will determine the level of success achieved by the SDA. Interagency interoperability requirements must be identified and reconciled to ensure agencies do not feel the integrity of current geospatial applications are compromised through participation in the SDA.

Agency geospatial systems planning will be integrated with the IT planning process administered by OIR – PRD.

Failure for an agency to participate in continuing geospatial systems planning will have adverse effects on the entire community of users. In the same way many analytical and cartographic products require several data themes to be effective, agencies need to recognize their contribution and responsibilities to reciprocating agencies that are dependent on data involved in the SDA. Agencies choosing not to participate, or to participate only in part in the SDA concept will derive minimal benefits from the SDA or BMP.

Principle #3: Hardware and Software Infrastructure

The State adopted Environmental Systems Research Institute (ESRI) Arc/Info as the GIS software standard in 1992 by resolution of the Information Systems Council. The SDA will rely on implementing this and other hardware and software standards. Specifically, this will involve Sun for Unix-based servers, Windows 2003 for Intel-based servers, and Oracle for database software. Mobile access standards will be determined in the future.

From the perspective of traditional IT analysis, an enterprise architecture for GIS will generate benefits and savings for the State and individual agencies. Providing central administration of core geospatial data products will allow agency users to focus on application development and data maintenance in line with their agency mission. The economy of scale for hardware, services, and application development will allow agencies to derive increased benefits from the same level of funding through time.

The delivery of Base Mapping Program data through the SDA represents a data resource approaching two terabytes. Many agencies have legacy application and data resources of significant size and complexity. As OIR has a responsibility for enterprise coordination of enterprise information technologies, GIS Services will coordinate this enterprise vision for geospatial data and services within State government.

GIS Services will be responsible for fostering agency interaction with the SDA infrastructure. From an organizational view, this will include leading the development of a database design that will result in the SDA being responsive to the broadest possible user base. From a technical perspective, this responsibility will extend to ensuring the functionality of the geospatial warehouse, documenting application development and data maintenance recommendations, and providing associated technical support services as requested from agencies. GIS Services will also consolidate and coordinate shared services and application development to manage costs and enable agencies to maximize investments in geospatial technologies.

Principle #4: Personnel Classification

Many of the personnel issues facing public sector IT professionals are amplified in the GIS world. Recruitment and retention, continuing training, and competition with the private sector in a competitive, technology-driven environment are challenges familiar to IT managers. Markets for geospatial technologies have rapidly expanded over the last two decades; experience can represent an overvalued commodity in this highly specialized job market. Job market competition is further heightened by the rapidly changing technology and the pursuit of individuals that simultaneously display technical skills along with a strong disciplinary background for applying these skills. Support for developing a competitive and responsive GIS personnel track is a need across all agencies developing a continuing geospatial systems plan.

Certification of GIS professionals is an active topic for various professional GIS organizations. GIS Services participates in this dialog through the National States Geographic Information Council (NSGIC) and the Tennessee Geographic Information Council (TNGIC).

Within the field of geospatial technology there is on-going debate on whether GIS is a profession or a tool. An argument can be made that both alternatives can lead a healthy, even symbiotic, coexistence. GIS as a tool is represented through existing applications currently used by a number of agencies. Today's geospatial tools and technologies are as valuable as traditional tools and methods to engineers, biologists, and planners.

The concept of GIS professionals encompasses the unique skill sets required to support enterprise planning and provision of services to these other professionals. These skill sets include very technical and directed application of database design, application development, and digital infrastructure management skills specifically tailored for geospatial information systems. Successful implementation of the Spatial Data Architecture will require qualified GIS professionals within the agencies to maximize this State investment.

Through the long-term implementation of the SDA, the personnel requirements of GIS Services will increase to reflect the growing responsibility for providing services to agencies. This will not manifest a scenario for centralizing all GIS-related services in State government, but will recognize the need for GIS skills within agencies. The agency needs for personnel skilled in domain-specific analysis and application development do not warrant centralizing all GIS personnel in State government.

Principle #5: Intergovernmental Benefits

The greatest potential of the Base Mapping Program and Spatial Data Architecture is to support intergovernmental data integration at the most fundamental level. Local governments manage the provision of services at the most elemental level; State and Federal government services depend on similar needs for geospatial data. If the singular benefit for developing intergovernmental cooperation were to distribute the expense of producing and maintaining geospatial data, the initiative would be considered successful. This benefit pales in comparison to the potential advantages of application integration and data sharing made possible by the adoption of a common geospatial database. Through the development of the BMP and SDA, Tennessee is well positioned to advance initiatives in this arena across many different governmental sectors including economic development, emergency services, transportation, and environmental and resource management.

Adopting the Spatial Data Architecture will serve as a foundation for other levels of government to interact with State government spatial data. The SDA and the associated enterprise plans of agencies will provide a singular, holistic view of geospatial data and applications. Once the SDA architecture design is in place, local governments can develop applications to take advantage of SDA benefits where appropriate. An example in this case would be the possibility of supporting comprehensive emergency response to combine information related to local services and State services. The singular interface of the SDA will also promote robust integration of Tennessee programs with federal geospatial data initiatives.

Principle #6: Enterprise Data Distribution Policy

Participation in the Spatial Data Architecture concept by agencies may lead to differing interpretations of implementation and policy. An area where this has critical implications is data distribution policy. All agencies need to be respectful and conscious of varying differences in agency policies. Customers of spatial data products may become aware of these potential conflicts and may make requests to one agency to otherwise circumvent a policy established by another agency.

TCA 10-7-506: Public records having commercial value addresses mechanisms for state and local governments to recover costs for the development and maintenance of spatial data resources.

A solution to this challenge will be implemented using three primary points. First, agencies will identify all geospatial data products available to outside resources and declare whether or not each product has associated commercial value. This identification will be associated with the continuous geospatial systems planning process.

Second, agencies distributing data that has commercial value on a transactional basis via the Internet will need to provide this data through the State Portal. GIS Services will lead the implementation and management of this service with the participation of agencies providing data.

Third, all geospatial data products within state agencies will be documented through a spatial metadata clearinghouse, referenced in the first principle. Each geospatial dataset or series will have an associated metadata record. Embedded in this record will be the appropriate information for security control and accessing the dataset described. The compilation of these metadata records and query and retrieval mechanisms will be designed so that one set of metadata records will respond to internal (intranet) requests as well as external requests.

Hardware and Software Guidelines

Overview

Components of Spatial Data Architecture infrastructure implementation utilize the State's technical architecture. This will include GIS products from the State's selected software products, from the State's selected Unix platform (Sun), Windows platform (Microsoft), and database software vendor (Oracle). As additional functionality is required, tools and products will be evaluated for developing standards recommendations.

The SDA advocates implementing BMP data in a geospatial data warehouse, accessible to agencies for data access and application development. Analytical applications for agencies and support applications for managing the geospatial data warehouse will be maintained in a client server environment.

Geospatial Data Infrastructure

Figure 1 represents the geospatial data infrastructure of the SDA. The larger central oval represents the infrastructure to support the access and maintenance of BMP data. The smaller ovals at the bottom represent existing agency infrastructures. They can also represent local government partners of the BMP. The small boxes attached to the agency ovals represent end users of geospatial applications. The boxes at the top of the graphic represent access for users of the SDA external to the BMP; for example, citizens, local governments, academic institutions, or private sector firms.

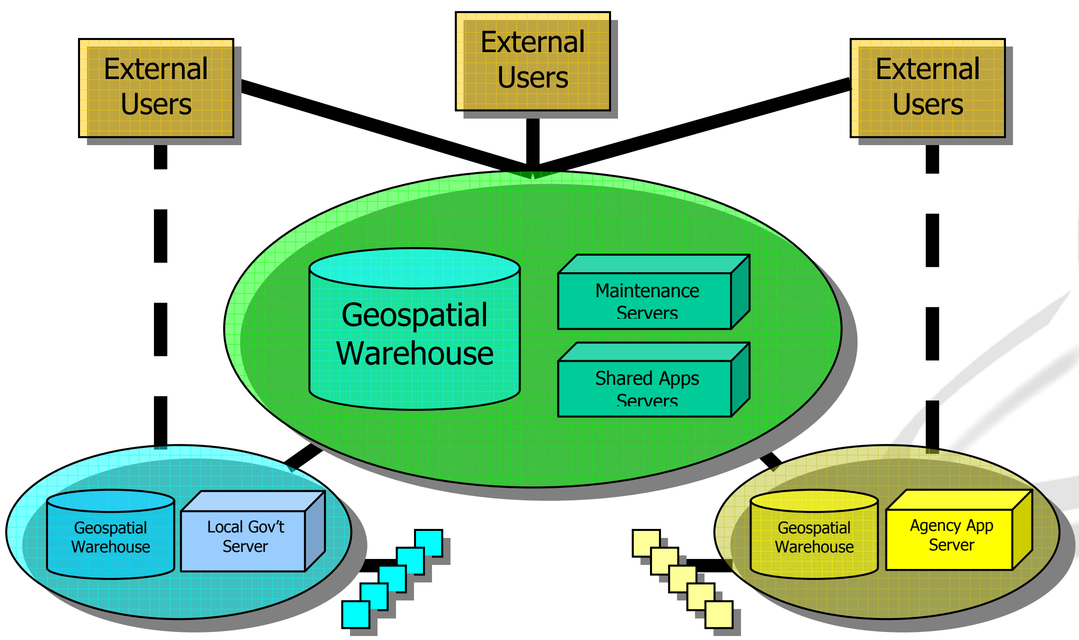

Figure 1: Geospatial Data Infrastructure of the Spatial Data Architecture

Storage Requirements

The spatial components of spatial data will be stored in a spatial data warehouse; proliferating multiple versions of the dataset will be inefficient and hinder spatial data interoperability. The attribute components of spatial data will be more flexible. Because minimal attribution is provided through Base Mapping Program data production, agencies are envisioned to be the primary source for thematic attributes. The use and value of this data resource will depend on conflating attribute data from agencies' existing spatial datasets. Performance for data access throughout the geospatial data infrastructure will be increased if the thematic attributes are stored concurrently with the spatial components. Agencies may choose to store sensitive attributes in a local relational database, using a primary key to link data from a secured database to the spatial components accessed from the spatial data warehouse.

The spatial data warehouse will utilize ESRI's Spatial Database Engine (SDE) to store data in an Oracle database on a Sun platform. Agency applications will access data from this server via the state network. The size of the BMP database is projected to be two terabytes; additional storage space will be necessary to accommodate agency legacy data sets concerning alternative themes not produced as part of the BMP program.

Processing Requirements

The Spatial Data Architecture prescribes client/server architecture for the developing geospatial systems and applications. In the context of GIS, the client/server paradigm provides the best solution for optimizing services for data warehousing and application development. Production servers are recommended by ESRI in enterprise implementations. This client/server paradigm supports the familiar IT benefits of scalability and isolation of applications.

Maintenance servers will support back-end geospatial warehouse functions. Applications servers will support the use of geospatial data from the warehouse.

To support the scalability and isolation of applications, production servers will fall into two categories: maintenance servers and application servers. Maintenance servers will host services for management and support of the geospatial warehouse. Examples of maintenance services include integration of transactional updates for spatial components, and automated fulfillment of data requests.

Applications servers will host services for analyzing spatial data stored in the geospatial warehouse. Examples of application services include web-map serving to Intranet or Internet clients and services used to perform geospatial analysis at the central site and delivery of these results to the requesting client application.

GIS Services will be responsible for operating and maintaining shared application services and maintenance services for the geospatial warehouse. GIS Services will develop services for agencies to provide economy of scale and amortization benefits for commonly used application services. Agencies will be encouraged to develop applications using these servers where economically feasible.

Database Design

The database design for the Spatial Data Architecture will begin by extending the scope of the Base Mapping Program Technical Specifications. As noted previously, BMP specifications produce very accurate spatial components, but minimal attribution components. These attributes will be derived from legacy agency systems or created through partnerships with custodian agencies.

GIS Services will coordinate and implement the SDA database design, but the success of the design will depend on agency involvement in the development of the specification.

Implementing continuing geospatial systems planning at the agency level will provide a comprehensive review of agency plans to guide the evolving development of the Spatial Data Architecture database design. GIS Services will coordinate this evaluation with the community of geospatial users. It is critical for agencies to participate in this development process to ensure respective agency requirements are met by this database design. Due to the nature of this process, the activities involved in continuous geospatial systems planning will play a substantial role in defining the scope and details of an agency's database design requirements.

The articulation of agency database requirements coupled with the enterprise database design will provide the guidance for agency migration plans of applications and data. As the implementation of SDA becomes more mature, agencies will develop migration strategies for renovating applications to take advantage of SDA benefits. They will determine what functions will need to occur to ensure the agency's substantial investment in legacy data and data structures are modernized to be compatible with the SDA.

Application Development

With the development of the geospatial data infrastructure and the Spatial Data Architecture database design, the stage is set for applications development based on these foundational components. Three classes of applications are identified: *Client/Server Applications*, *Intranet Applications*, and *Internet / Portal Applications*.

Client/Server Applications

Client/server applications are defined as implementations that involve a dedicated geospatial application running on the end-user's desktop environment. Typical ESRI products that represent these geospatial applications are ArcMap, ArcView, or thin clients based on ArcObjects. These applications will access data from networked geospatial warehouses at the agency or enterprise level. Processing and functionality for these applications takes place through the use of a menu driven interface, command line, or scripting.

ESRI's next generation of interfaces is based on *ArcObjects* technology. This supports modification of client applications, functionality, and geospatial data distribution through a Visual Basic-based library.

An increasing trend in the field is to distribute very thin client interfaces dedicated to viewing and interacting with geospatial data while providing central processing for advanced analytical functionality. Within the geospatial data infrastructure, this architecture can be accommodated through the use of application servers hosting services developed for this purpose.

Intranet Applications

Intranet applications are defined as implementations that involve providing access to geospatial applications from a browser-based environment within the State's Intranet infrastructure. The primary source for these applications will disseminate from ESRI's Arc-Internet Map Server (ArcIMS) technology. ArcIMS will run from application servers at the agency or enterprise level. The geospatial data to drive these applications can also come from either the agency or enterprise level.

GIS Services will develop and manage shared geospatial services. ArcIMS technology will be one of the first technologies to be developed as a shared service. ArcIMS also provides a services framework for developing and managing additional application services.

Internet / Portal Applications

The ArcIMS application builds and administers the user interface and back-end processing services concurrently.

Internet applications are defined as implementations that involve providing access to geospatial applications and data to users outside of Tennessee state government from a browser-based environment. Similar to the intranet applications category, Internet applications will be served through ArcIMS.

Developing interfaces and delivering geospatial applications to professional users comfortable with the principles involved is challenge enough. Adding the additional issues of providing this data and technology to the general public having a wide variety of skill levels and even wider range of potential queries makes addressing the scenario more difficult. GIS Services will develop and maintain an ArcIMS-based application to be linked to the State Portal to provide a base map application that will utilize and display data developed by agencies. Additionally, agencies will have an opportunity to create agency-specific map-based services for the public, presuming interface guidelines are followed. The creation of these interface guidelines will be coordinated by GIS Services and will involve the portal vendor and interested agencies.

GIS Services will also coordinate with the State's portal vendor to address issues of cost recovery from public data transactions based on Internet data delivery. According to the State's Portal contract, the portal vendor is to provide the interface for developing public applications. The primary motive for this policy is to maintain consistency in interface presentation to the public and streamline cost recovery for agencies.

Data Distribution

Data distribution within the context of the geospatial data infrastructure addresses the distribution of geospatial data resources to government agencies or users external to State government. As part the continuous geospatial systems planning process, agencies will need to identify situations where data transactions take place.

The need for the community of agencies to respect the differences and interpretations of "commercial value" and distribution practices cannot be stressed enough. GIS Services will provide information on the relevant issues and create a consensus position on the commercial value for geospatial data. In any respect, agencies involved in data distribution will be expected to maintain audit records and distribution practices consistent with the SDA principles.

Data distribution transactions can take one of three forms: *Service Transactions*, *Data Sales*, or *Subscription Sales*.

Service Transactions

Service transactions are transfers of geospatial data to support contractual projects, or transfers of geospatial data identified as having no commercial value. In the geospatial data infrastructure diagram (see Figure 1, page 7), this transaction is shown as a dashed vertical line directly connecting from agency domains to external users.

This does not preclude the transfer of geospatial data that has been identified as having commercial value, as long as this data is not BMP data, nor contains spatial or attribute components contributed to the spatial data warehouse where this might conflict with another agency's cost recovery policy as supported under TCA 10-7-506. Each agency seeking to support service transactions will need to produce sufficient documentation for auditing transactions that may be covered by this circumstance. Additionally, GIS Services will coordinate with agencies to draft generalized licensing language appropriate for use in these scenarios.

Data Sales

Data sales transactions involve the incremental transfer of geospatial data identified as having commercial value. In the geospatial data infrastructure diagram (see Figure 1, page 7), this transaction is shown as the confluence of user links at the top of the central oval.

The technical implementation of data sales may be handled by individual agencies in the instance where data is transferred using conventional media, data external to the agency is not involved, or data through maintenance services supporting the geospatial data warehouse is not involved. In either instance, supporting infrastructure for data reproduction and delivery mechanisms will be closely related to clearinghouse functionality for discovery and retrieval of geospatial data.

As discussed in the Internet/Portal Applications section, the State's selected portal vendor is responsible for accounting and transactions involving the Internet delivery of services. GIS Services will coordinate with agencies to implement these requirements and create acceptable licensing language.

Subscription Sales

Subscription sales transactions involve the access of geospatial data identified as having commercial value. Subscription sales are closely related to data sales in concept and are not separately represented in the geospatial data infrastructure diagram.

Subscription sales may be handled by agencies or by GIS Services when involving BMP data. Subscription sales represent a one-time or ongoing contractual arrangement for a copy of a portion of a geospatial warehouse database, periodic updates from a geospatial warehouse database, or limited access to a geospatial warehouse database. Agencies intending to process subscription sales will need to document this in the agency's continuous geospatial systems plan.

The differentiating factors between subscription sales and data sales are the method of access and method of transacting payment. In the data sales scenario, a contract is utilized to audit transactions. In the subscription sales scenario, a traditional services contract captures the transaction. In the data sales scenario, a credit card or debit account will be used to transact payment, while in the subscription sales scenario, contractual forms of payment between the customer and the State are employed.

Roles and Responsibilities

This section provides a review of the roles and responsibilities identified for GIS Services and participating agencies in the implementation of the Spatial Data Architecture. Each of the responsibilities is categorized within the most applicable related principle.

GIS Services

- Spatial Data Sharing
  - Lead SDA planning and implementation
  - Develop and monitor custodian responsibilities for SDA datasets
  - Assume custodian responsibilities for orthoimagery
- Continuous Geospatial Systems Planning
  - Develop continuous geospatial systems planning as part of the IS Planning process
  - Coordinate distribution of geospatial systems plan
  - Review and reconcile issues within agency geospatial systems plans
- Hardware and Software Infrastructure
  - Develop and implement services of the geospatial data infrastructure
  - Respond to agency and local government needs for geospatial data infrastructure services
  - Develop protocols for agency applications utilizing the geospatial data infrastructure
  - Ensure provision of geospatial data infrastructure services
  - Lead development of SDA database design
- Personnel Classification
  - Lead establishment of GIS professional classification track
  - Support GIS agency users by facilitating the State GIS users group
- Intergovernmental Benefits
  - Develop supporting educational materials for local and federal partners relating to SDA and geospatial systems planning
  - Participate in developing intergovernmental opportunities based on BMP, SDA, and geospatial systems planning
- Enterprise Data Distribution Policy
  - Lead development of enterprise data distribution practices
  - Develop informational material for agencies on data distribution issues
  - Develop template language for data distribution licensing
  - Lead development of portal mapping application for State Portal
  - Lead development of State Portal geospatial data distribution application
  - Coordinate with State Portal vendor issues relating to cost recovery for geospatial data
  - Document data distribution transactions as appropriate

Agencies

- Spatial Data Sharing
  - Participate in SDA planning and implementation
  - Participate in developing custodian responsibilities
  - Accept appropriate custodian responsibilities
- Continuous Geospatial Systems Planning
  - Participate in developing continuous geospatial systems planning
  - Develop agency geospatial systems plan
  - Participate in reconciling issues within agency geospatial systems plans
- Hardware and Software Infrastructure
  - Participate in SDA database design
  - Develop future applications based on geospatial data infrastructure
  - Evaluate and migrate data and applications to take advantage of geospatial data infrastructure
- Personnel Classification
  - Recognize personnel requirements for GIS professionals and support for GIS users in agencies in geospatial systems planning
  - Update responsibilities to accurately reflect responsibilities and requirements for GIS users
  - Identify personnel to participate in the State GIS Users Group and promote dissemination of SDA and BMP information
- Intergovernmental Benefits
  - Participate in developing intergovernmental opportunities based on SDA and geospatial systems planning
- Enterprise Data Distribution Policy
  - Participate in development of enterprise data distribution practices
  - Identify data distribution scenarios in geospatial systems plan
  - Participate in development of portal mapping application for State Portal
  - Participate in development of State Portal geospatial data distribution application
  - Document data distribution transactions as appropriate

Appendix A: Infrastructure Components and Scenarios

Overview

The Spatial Data Architecture addresses the support for geospatial data and applications in Tennessee State government. The principles and guidelines of the document provide an enterprise vision for the implementation of the SDA. To preserve this enterprise focus, technical specifications and prescriptive solutions are not appropriate. Integrating technical details in these sections of the document diverts focus and would create an environment of iterative reevaluation as hardware and software capabilities evolve through time. However, given the specialist nature of geospatial technology, illustration of technical points of the implementation can provide clarification for GIS managers and for the wider IT community.

This appendix will present a review of the components involved in the SDA, an interpretation on how these components can be implemented, and how existing government agency infrastructures will interface with the geospatial data infrastructure. It is important to recognize the illustrative details used in these sections reflect current technology. Through time, these sections will be updated to reflect improvements in hardware and software. These revisions will represent a refinement on interpretation of the SDA, and will not represent conflicts or contradictions to the principles or guidelines of the SDA.

Review of Components

The Hardware and Software Guidelines section of the SDA outlines three major hardware/software components to the Geospatial Data Infrastructure: the Geospatial Warehouse, Maintenance Servers, and Application Servers. These provide the primary structural components for the geospatial data infrastructure.

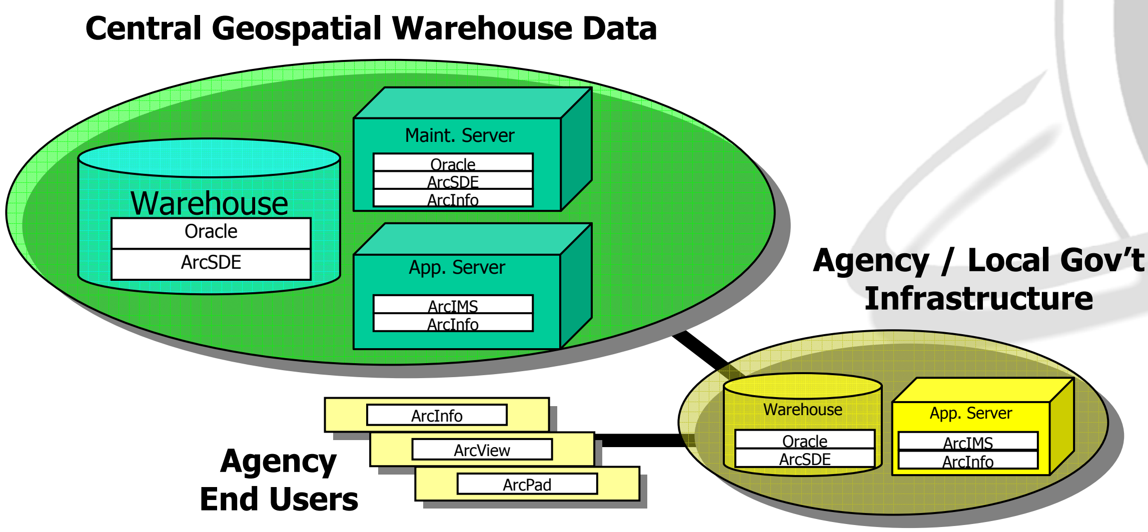

Figure 2: Components of the Geospatial Data Infrastructure

The components support a client/server paradigm for managing geospatial data and applications. Figure 2 shows the components of the Geospatial Data Infrastructure, including application software associated with each component.

Geospatial Warehouse

The geospatial warehouse maintains geospatial data for application servers. The geospatial warehouse for supporting BMP data will involve two terabytes of online storage. The geospatial warehouse will provide data for end user applications, and will serve as the evolving repository for the most up-to-date BMP data, as well as historical geospatial data.

Accessing spatial components and attribute components in separate databases is managed in the application environment. This allows the database service to manage security.

The hardware used to support geospatial databases of this size is commonly run on Unix servers. Sun hardware using the Solaris operating system is the lead development environment for ESRI software for Unix implementations.

The application software used to host the geospatial warehouse will be a combination of products from ESRI and Oracle. The *geodatabase* is ESRI's data model for representing geospatial data in a digital environment. This model is based on object-relational database structure, and represents a significant improvement from the entity-relational model used by ESRI's ArcInfo product since its inception in the early 1980's.

ESRI's Spatial Database Engine (SDE) software provides a maintenance interface and application interface for storing geospatial data in a number of SQL-compliant, commercial database applications. Oracle and Microsoft SQL Server are both supported by SDE. The SDE maintenance interface allows users to monitor and optimize database performance without being a specialist with the vendors optimization tools. The SDE application interface utilizes maintenance services for clients to serve data requests.

Oracle will manage the tables required to store the geospatial data. Storing the data in a relational database management system (RDBMS) promotes flexibility in managing potentially sensitive attribute components of geospatial data. Managing access to these components can be facilitated through traditional permission protocols within the RDBMS environment; Oracle and SDE can use these permissions to join spatial components and attribute components from different tables (or even from different databases or database environments) when delivering the data to the end user application. Ongoing support requirements for Oracle maintenance will be minimal; once the warehouse implementation is in place, SDE provides tools for common maintenance tasks.

Maintenance Servers

Maintenance servers are one of two types of production servers within the geospatial data infrastructure. Maintenance servers provide the services related to managing the geospatial data in the geospatial warehouse. Within the client/server paradigm, it is important to isolate applications to promote flexibility in optimization for performance, scalability, and security.

Maintenance services related to managing geospatial data will deal with data maintenance functions and data distribution functions. Data maintenance functions involve integrating update transactions to data in the geospatial warehouse. Since the geodatabase data model used by ESRI supports versioning, maintenance services will also be responsible for supporting these functions.

Services related to data distribution will also be handled through maintenance servers. Data distribution in this context involves automated or semi-automated downloading and preparation of data sets requested from external users for delivery on media. (Providing data to client applications in real time is covered in the next section.) This isolates these applications from future scalability issues relating to either the maintenance server or geospatial warehouse. It also supports the development of a flexible and responsive application environment for interfacing with the State's portal vendor services as appropriate.

Versioning in the geodatabase is managed through the geodatabase object model. SDE can manage versioned and non-versioned geodatabases.

ESRI will provide recommendations for server hardware needed to support maintenance services based on capacity and projected growth through time. Maintenance services for supporting the SDA are available for both Windows and Unix platforms. The determining factors will be the need for scalability, initial capacity, and the pace at which the capacity of maintenance services is projected to increase. Through the production of BMP data, the warehouse capacity and complexity will increase as more data and users access these services. In the majority of cases, ESRI recommends Windows –based services when initial capacity does not justify investing in Unix machines. An economic analysis favors a smaller initial investment in Windows servers that can quickly be augmented if scalability needs arise; the price to performance ratio of Windows servers can also enable the environment to be more responsive to increases in processing capacity.

Application Servers

Applications servers are the second type of production servers within the geospatial data infrastructure. Application servers provide the services related to processing and presenting geospatial data to client applications. Applications services can involve processing orthoimagery for optimal presentation across networks, building graphical representations of vector data for serving to low bandwidth clients, browser-based applications, or even streaming vector-based geospatial components to a heavy client.

The requirements for the variety of potential application services underscores the need for a robust client/server environment. Scalability and optimization come to the fore and can be easily addressed if the services and associated hardware and software are sufficiently segmented.

In general, application services are less flexible with respect to operating system requirements. This is a reflection of the highly optimized nature of application service functionality; they are built to execute a limited set of tasks very efficiently. ESRI's ArcIMS environment provides an application framework for managing application services. These services can run from Windows or Solaris operating systems.

Geospatial Data Infrastructure

The geospatial data infrastructure referenced in Figure 1 (page 7) gives a generalized overview for the flow of geospatial data and applications within Tennessee government. It also addresses data flows between agencies and external users.

The large central oval represents the geospatial warehouse, maintenance servers, and application servers related to the provision of Base Mapping Program data. GIS Services will be responsible for ensuring the provision of these geospatial data and services. As indicated earlier in the Appendix, the warehouse hardware will run on Sun and Solaris, with the associated production servers being an optimized mix of Sun and Windows servers.

The two smaller ovals represent agency and local government partner infrastructure components. The infrastructure components include a geospatial warehouse, agency application server(s), and end users. Through continuous geospatial systems planning and adoption of the SDA, agencies will move toward services provided by the central oval. Through this transition period, agencies will still operate legacy applications and maintain legacy geospatial data. As the SDA matures, the majority of the state's data requirements will be served by the central geospatial warehouse. Agencies will have the opportunity to maintain their own warehouses in instances relating to sensitive information and supporting legacy systems. Efforts will be made through the review of agency plans to identify possible duplication of effort and maintenance of redundant data sets. Over time, these applications and data sets will be expected to move towards practical integration with SDA geospatial data and services as appropriate.

Even though these warehouses will serve critical functions, it is unlikely that these agency warehouses will need dedicated maintenance servers for maintenance functions.

Agencies will also have the opportunity to maintain agency application services where appropriate needs exist. These servers will maintain discipline specific services not offered by GIS Services. In the case where an agency indicates they intend to establish an agency application service that duplicates an existing centralized service, agencies will provide justification for the duplication of service.

The true test for the Spatial Data Architecture will be the application of geospatial data for end users. The infrastructure has been created with the goal of serving the complete spectrum of clients. This includes thick clients (for example, desktop applications such as ArcMap and ArcView), medium clients (for example, ArcExplorer), thin clients and web-based applications (both Intranet and Internet –based) and eventually wireless applications such as ArcPad. Each of these clients will draw on different application services in varying capacities.

Agency Implementation

The evolution and development of geospatial technologies has historically taken place at the agency level. Each agency has developed data and applications to meet the immediate internal requirements. The investment by the State in the Base Mapping Program represents a substantial change in perspective for the management of geospatial data and applications. The implementation of the Spatial Data Architecture will not happen as a cutover, rather it will be a gradual shifting as data and services are put into place.

More important than the shift in technology is the requisite shift in culture. This is underpinned by the recognition of the IT community and GIS managers' for the need to balance agency requirements with enterprise responsibilities. Agency involvement will produce the success and return on investment originally envisaged that has justified the State's commitment to the Base Mapping Program. ***Participation by agencies will result in a mature Spatial Data Architecture that will enable agencies to focus on agency missions, rather than data development issues.*** Over time, agencies will experience benefits from the collective nature data maintenance. Through standards and a comprehensive planning process, agencies will be assured of dependability when using products and services from one another.

Legacy data and applications are the foremost concerns of agencies. Over the years, the development of these data sets and applications represent significant investments on the part of agencies. These also represent the current infrastructure for supporting the provision of services by agencies. Active participation in the continuous geospatial planning process and database design process is the best way to ensure agency requirements are addressed within the framework of the SDA. Conversely, giving participation in this process a low priority will have negative long-term impacts on the State's and an agency's ability to draw benefits from the SDA.

Agencies with a long history of geospatial data and applications will undoubtedly have concerns about agency infrastructure components. Through the migration of legacy data, periodic update and maintenance of legacy application, and commitment of developing geospatial applications within the SDA, legacy equipment will not be a long-term issue. This process provides an opportunity for transitioning applications and services from legacy equipment to centralized services, or agency services that are tightly integrated with SDA infrastructure.

Glossary

application server – A component of the geospatial data architecture dedicated to running applications services using data from a geospatial warehouse.

application service – A service run from an application server designed to utilize data from a geospatial warehouse. An example of an application service would be a web-mapping service.

ArcIMS – (Arc-Internet Mapping Service) A commercial application provided by ESRI for developing applications services. The most popular service is a web-application service. ArcIMS simultaneously builds and manages the user interface and the analytical and display functionality of the web mapping application.

ArcInfo – A commercial GIS application from ESRI. ArcInfo is marketed towards professional users.

ArcPad – A commercial GIS application from ESRI. ArcPad is thin-client application for PocketPC-class machines. It is optimized for use in wireless application development.

ArcView – A commercial GIS application from ESRI. ArcView is marketed towards application users.

attribute component – The component of spatial data involving the measurement and storage of attributes about a spatial data feature.

clearinghouse – An application based on Z39.50 protocol for the indexing and distributed query and retrieval of metadata records related to geospatial datasets.

conflation – The process of comparing two spatial data sets for the purpose of transferring updates of spatial or attribute components from one dataset to another.

Content Standard for Digital Geospatial Metadata (CSDGM) – The current metadata standard for documenting geospatial data.

custodian – Agency or agencies that accept responsibility for coordinating maintenance for a geospatial dataset involved with the SDA.

data sales – Distribution of geospatial data maintained by a government agency through distribution on an incremental basis for a fee.

database design – Specification based on BMP technical specifications, and extended to meet the needs of SDA users.

Environmental Systems Research Institute (ESRI) – Commercial vendor of GIS software selected as State standard by ISC in 1992.

Federal Geographic Data Committee (FGDC) – Federal secretariat designated to coordinate Federal GIS activities. FGDC maintains several nationally recognized standards, including CSDGM.

geodatabase – The data model used by ESRI for representing geospatial data in an object-relational data structure.

geographic information system (GIS) – A digital system designed for the creation, management, analysis, and display of geospatial information.

geospatial application – An application designed to operate on geospatial information.

geospatial data – A digital representation of a real world feature with attributes describing characteristics of the feature and its location.

geospatial data infrastructure – The hardware, software, and personnel required to implement the vision of the SDA.

geospatial systems plan -- A plan for the immediate and long-term development of geospatial data and applications within an agency.

maintenance server -- A component of the geospatial data architecture dedicated to running applications services for maintaining the data in the geospatial warehouse.

maintenance service -- A service run from an application server designed to serve or maintain data from a geospatial warehouse. An example of a maintenance service would be an application for loading updates of data to the geospatial warehouse.

metadata – A formatted record using CSDGM for describing characteristics about a geospatial dataset.

portal application – An internet-based application using geospatial data designed to serve users external to state government.

service transaction – Distribution of geospatial data to support contractual obligations, or distribution of data having no commercial value.

Spatial Database Engine (SDE) -- A commercial application from ESRI designed to support the processing of geospatial data using commercial database products.

spatial component – The component of spatial data storing the geometric representation of a spatial data feature, or a reference to a geometric representation, or a reference to a real-world location.

spatial data architecture (SDA) – The enterprise vision for coordinated implementation of geospatial data across government in Tennessee.

subscription sales – Distribution of geospatial data, or provision of access to a geospatial warehouse maintained by a government agency on a contractual basis for a fee.

Tennessee Base Mapping Program (BMP) – Five year program to produce essential geospatial data for analytical and cartographic products and services in cooperation with local governments.

BMP technical specifications – Production specifications used in creating BMP geospatial data. Resulting products represent high-resolution and extremely accurate data with limited attribute components.